Long-Term Skid Resistance of Asphalt Surfacings and Aggregates' Mineralogical Composition: Generalisation to Pavements made of Different Aggregate Types

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Abstract

The work presented in this paper aims to find the relationship between the types of coarse aggregates used in asphalt mixes and the long-term skid resistance capacity of the resulting pavements. It builds on previous work which proposed a relationship between the mineralogical composition of aggregates and the skid resistance of asphalt surfacings in the long-term. Here, the focus of the inquiry is shifted from an asphalt surface of one type of aggregate to a mix of several types of aggregates. Polishing tests and friction measurements were performed in the laboratory on different pavement samples, followed by a mineralogical analysis of the coarse aggregates of these samples to define a new parameter termed "Averaged Aggregate Hardness Parameter". The results found that this parameter correlates well with the long-term skid resistance. Finally for practical use, the paper proposes analytical formulas to link the new pavement hardness parameter with the long-term skid resistance of pavements.

Keywords

Long-Term Skid Resistance; Asphalt Surfacings; Aggregates' Mineralogical Composition; Petrographic nature; Aggregates types; Averaged Aggregate Hardness Parameter; Polishing, Traffic

Introduction

Skid resistance describes the contribution that the pavement surface makes to tire/road friction. It is a measurement of friction obtained under specified, standardized conditions, determined to fix the values of potential variable factors so that the contribution that the pavement provides to tire/road friction can be isolated [Kane and Scharnigg, 2009]. It remains one of the most important parameters for the safety of road users. Indeed, maintaining adequate skid resistance contributes to drivers being able to control their vehicles (stopping distance and trajectories). Skid resistance is highly dependant on the texture (macrotexture and microtexture) present at the surface of the pavement, and an adequate level of skid resistance is therefore desired throughout the life of the pavement [Moore, 1975]. To achieve this, the pavement components, and in particular the aggregates, are carefully selected after a multitude of tests such as Polished Stone Value (PSV), Micro-Deval co-Efficient (MDE); LA Los Angeles (LA), etc [NF EN 1097-8, Lédée et al., 2005, Woodward et al., 2005]. Depending on the country policies, only aggregates reaching limit values of the above tests are used to build pavement wearing courses.

However, the skid resistance of pavements will evolve continuously throughout their lives. When the pavement is of asphalt type, and at a young age, it will have a low skid-resistance due to the masking of the aggregates on its surface by the bitumen binder. However, as time passes, the binder is stripped and the more the skid resistance increases [Do et al., 2007 and 2009]. At the end of the stripping process, generally corresponding to about six months (this duration is an average, indeed this stripping time will greatly depend on the aggregate/bitumen interface, but also many parameters related to the field environment), the skid resistance reaches its maximum and then starts to decrease due to the polishing of the aggregates, which are now exposed. This decay will continue up to a limiting value, which depends exclusively on the type of aggregate and particularly on the aggregate's ability to retain or renew its microtexture [Do et al., 2007 and 2009, Tourenq and Fourmaintraux, 1971, Masad et al., 2009]. In the case of a mosaic of aggregates (aggregates glued directly to a surface), this stripping phenomenon will not occur. The initial skid resistance of such a surface will start high, but will gradually decrease with polishing towards a limiting value depending on the type of aggregate. In either case, where the same type of aggregate is used whether in an asphalt sample or in a mosaic, they will roughly reach the same skid resistance after polishing [Do et al., 2007, Kane et al., 2013].

The ability to retain or renew microtexture is primarily dependent on the minerals that make up the aggregates, especially their hardness. If the minerals are hard, it will be difficult to remove them through polishing and other actions, and therefore the aggregates will better retain their microtexture. As a result, the level of skid resistance on the pavement surface is retained. Whereas if the aggregate's minerals are soft, polishing will be easier, leading to smooth aggregates with no microtexture on their surface and consequently low skid resistance on the pavement surface. If the aggregates are composed of a mixture of hard and soft minerals, the polishing will be more pronounced on the soft than on the hard, which will result in a continuous recreation of microtexture on the surface of the aggregates and thus maintain skid resistance [Tourenq and Fourmaintraux, 1971, Masad et al., 2009, Kane et al., 2013].

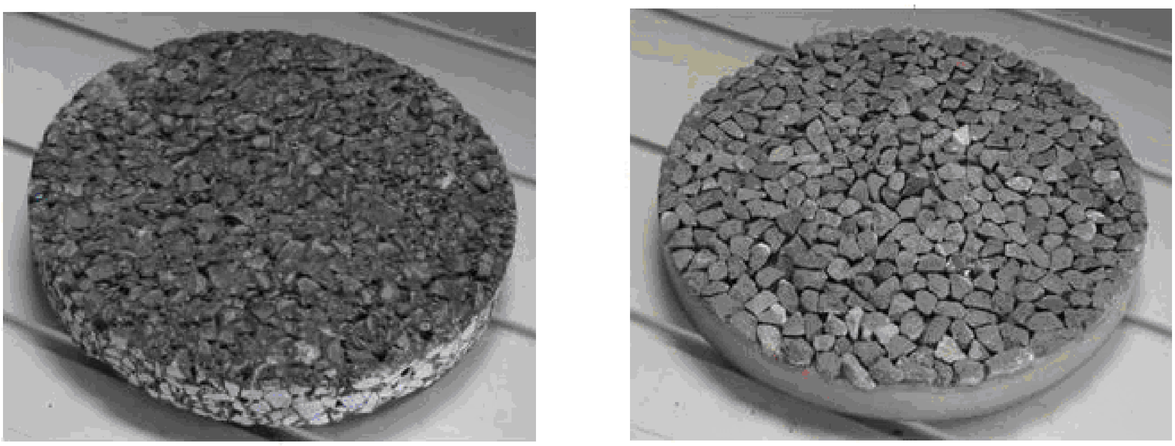
In a recent publication, Kane proposed a relationship between the hardness of minerals; the hardness to softness contrast of the minerals in aggregates; and the long-term skid resistance of the pavement surface [Kane et al., 2013]. This relationship remains valid as long as only one type of aggregate is used in the pavement surface. In this work, the authors generalize this relationship to the case of a pavement composed of different types of aggregates. New samples of pavements composed of different aggregates will complement those used in the previous publication for the generalization of the relationship.

First, the previous relationship will be recalled and developed into a generalized form. Secondly, the additional samples will be presented including the device that performs the polishing (simulating traffic) and measures the skid resistance afterward (long term). The final third part of the paper will be devoted to the validation of the parameters arising from the new generalized formula by comparison with the results of the skid resistance after polishing. Finally for practical use, the paper proposes analytical formulas to link the new pavement hardness parameter with the long-term skid resistance of pavements.

Generalization of the skid resistance relationship

Typical evolution of the skid resistance of an asphalt pavement subjected to traffic polishing

In the study undertaken, mosaic or asphalt samples will be used indiscriminately (Figure 1). The mosaics of aggregates are fabricated by gluing the aggregates directly to a rigid surface and the asphalt surfacings are built with the same manufacturing conditions (the same aggregate size, compaction…).



Asphalt Mosaic

Figure 1: Left – Core extracted from asphalt; Right - Mosaics of aggregates prepared from size 7.2/10 mm aggregates

Reminding of the original model

In a previous study [Kane et al., 2013], the author defined a parameter called "Aggregate Hardness Parameter" (AHP) for pavements made by a single aggregate type (Equation 3). The AHP parameter correlated very well with the pavement skid resistance after polishing for both asphalt and aggregate samples. The AHP parameter is the sum of the "Average Hardness" (dmp, Equation 1) and the "Contrast of Hardness" (Cd, Equation 2) of the aggregates. These last two parameters were introduced by Tourenq [Tourenq et al., 1971], except that the author redefined them by replacing the Vicker's hardness by the Moh's hardness scale.

$$\mathrm{dmp} = \sum_i \mathrm{dv_i} \times \mathrm{p_i} \quad (1)$$

$$\mathrm{Cd} = \sum_i \left|\mathrm{dv_i} - \mathrm{dv_p}\right| \quad (2)$$

$$\mathrm{AHP} = \mathrm{dmp} + \mathrm{Cd} \quad (3)$$

where:

AHP means the Aggregate Hardness Parameter, dmp is the Average Hardness of the aggregates, Cd is the Contrast of Hardness of the aggregates, dv_i is the Moh's hardness of each mineral constituting the aggregates and p_i is the percentage by mass of each mineral constituting the aggregate. dv_p is the Moh's hardness of the most abundant mineral constituting the aggregate.

Generalizing to a mix of aggregates

To generalize the parameter AHP for the case of a surface composed of several aggregates (which might occur for instance on test tracks where skid resistance must have a well-defined level dependent on the use), it is assigned to an average AHP_M (Equation 4). The AHP_M parameter will be the average of the AHP_i for each aggregate "i" contained in the mixture, weighted by its proportional volume "α_i" to the overall volume of the "N" aggregate mixture:

$$\mathrm{AHP_M} = \frac{1}{\sum_i^N \alpha_i} \sum_i^N \alpha_i \times \mathrm{AHP_i} \quad (4)$$

Validation of the generalized model

Pavement samples

Eight circular 225mm diameter samples were used in the study, being either mosaics or asphalt mixes as defined in Table 1 by respectively the 'A' or 'M' notation. The mosaics are made by manually placing the 7.2-10 mm fraction sized aggregates in a mold packed as close as possible to each other to form a single layer, and then bonding the back of this layer with a resin. The asphalt samples are cored directly from the pavement (Figure 1). Mosaics (named M1 to M3) are generally composed of a single type of aggregate (results from these samples were already shown in the previous publication) whereas asphalt mixes SMA (named A1 to A5) are composed of a mixture of aggregates. Asphalt mixes, which are comprised of multiple-types of aggregate, are included here to compliment the mosaics, which contain a single type of aggregate. The table below (Table 1) details the characteristics of the samples, including the types of aggregate and the proportions by volume. Note that Surface A2 is 96% diorite and the remaining 4% the composition of which is not known yet.

Table 1: Sample characteristic including the type of aggregate and proportions by volume. The first letters "A" and "M" of the names of the samples gives their natures ("A" for Asphalt mixe and "M" for Mosaic)

		Aggregate types					
		Limestone	**Basalt**	**Quatzite**	**Diorite**	**Greywacke**	**Granite**
Sample names	**A1**	52	40	0	0	0	0
	A2	0	0	0	96	0	0
	A3	8	29	54	0	0	0
	A5	70	0	21	0	0	0
	A6	0	93	0	0	0	0
	M1	0	0	0	0	100	0
	M2	0	0	0	0	0	100
	M3	100	0	0	0	0	0

Petrographic examination of aggregate samples was carried out under BS EN 932-3: 1997 [Kane et al., 2013]. The general characteristics of the aggregate samples including maximum particle size, texture, and shape were examined and recorded. The main rock types were then identified and the relative proportions of the mineral constituents were estimated using a light (optical) microscope. Colour, grain size and degree of weathering were also recorded. To facilitate the quantitative examination, aggregate samples were sieved into separate size fractions and the mass of each size fraction determined. Each size fraction was then examined and the petrological composition was determined by hand separation and weighting [BS EN 932-3: 1997, Kane et al., 2013]. The method employed required two representative samples to be tested, with the result taken as the mean of the two measurements. Table 2 displays the mineral composition of each aggregate composed in the samples.

Table 2: Mineral composition of the aggregate contained in the samples

Aggregate type	Mineral type	Mineral composition (%)	Mineral Hardness (H) (1 - 10)
Limestone	Calcite	100	3
Basalt	Pyroxene Feldspath Olivine	30 50 20	5,5 6 6,5
Diorote	Pyroxene Feldspath	25 75	5,5 6
Quartzite	Quartz	100	7
Greywacke	Quartz Feldspath Chlorite Biotite	52 16 22 10	7 6 2,5 3
Granite	Quartz Feldspath Amphibole Biotite	27 49 19 5	7 6 6 3

Estimation of the Pavements' AHP_M

First, the APH parameter (see Equations 1-3) of each aggregate was calculated based on the constituent minerals, their percentage, and hardness (see Table 2). Table 3 below shows the AHP of each of the aggregates.

Table 3: Estimated AHP of each aggregate of the samples

Aggregate type	Mineral type	% x H	Average hardness (dmp)	Cd	AHP
Limestone	Calcite	3.0	3.0	0	**3.0**
Basalt	Pyroxene Feldspath Olivine	1.7 3.0 1.3	6.0	1	**7.0**
Diorote	Pyroxene Feldspath	1.4 4.5	5.9	0.5	**6.4**
Quatzite	Quartz	7.0	7.0	0	**7.0**
Greywacke	Quartz Feldspath Chlorite Biotite	3.7 1.0 0.5 0.3	5.5	9.5	**15.0**
Granite	Quartz Feldspath Amphibole Biotite	1.9 2.9 1.1 0.2	6.1	4.0	**10.1**

In a second step, having obtained the AHP parameter of each aggregate (See Table 3), the AHP_M (see Equation 4) parameter was calculated for the percentage of aggregates comprised in each of the samples (see Table1). Table 4 below shows the AHP_M obtained for each surface sample. These values were compared with the long term adhesion values of the surfaces.

Table 4: Estimated AHP_M of the surface samples

		AHP_M
Sample names	**A1**	4.72
	A2	6.38
	A3	6.63
	A5	3.92
	A6	6.95
	M1	15
	M2	10.1
	M3	3

Measuring the long-term skid resistance

The long-term skid resistance of a pavement surface corresponds to the ‘stabilized’ skid resistance value after a long period of polishing by traffic. To simulate this traffic polishing in an accelerated way and afterward measure the skid resistance, the Wehner-Schulze (WS) machine was used. The Wehner-Schulze machine has been demonstrated to effectively simulate the real traffic polishing many times [Do et al., 2007 and 2009, Kane et al., 2013]. The polishing process and skid resistance measurements were performed using the two different stations of the WS machine (Figure 2). The polishing station contains three rubber cones mounted on a rotary disc, which rolls on the specimen surface with an average pressure of 0.4 N/mm². To accelerate the polishing process, a mix of 5% quartz powder (< 0.06mm) in 95% water is sprinkled during the rotation of the cones. The surface is polished on a ring. The polishing process is programmed to stop after 180.000 number of rotations (corresponding roughly to 7.5 x 10^6 passages of trucks [Do et al., 2009]).

After polishing, the specimen is moved to the skid resistance measuring station. This station is composed of three small rubber pads each pad with a 4 cm² area disposed at 120° on a rotary disc. The contact load between the rubber pads and the specimen surface is approximately 0.2 N/mm². To proceed to the skid resistance measurement, the disc is accelerated until a speed of 100 km/h is reached. At that speed, water is projected on the specimen surface and the motor is stopped and the disc is dropped until the rubber pads touch the specimen surface. The rotation is stopped by the friction between the rubber pads and the specimen surface; the friction–time curve is then recorded. The skid resistance value recorded at 60 km/h is used for analyses.

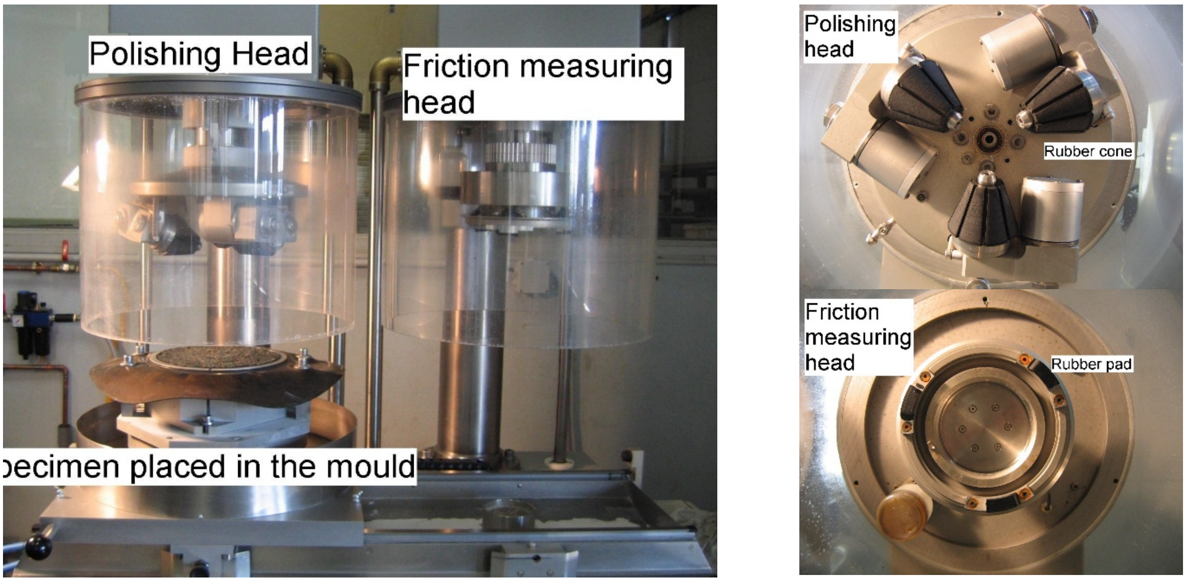


Figure 2: Left – Elevation view of the machine with two heads for respectively polishing and friction measurement. Right – Plan view of the two heads of the WS machine for respectively polishing (top) and friction measurement (bottom)

The polishing procedure detailed above is applied to the surface samples of Table 5. After 180.000 rotations, the skid resistance is measured and the value is given to consider to represent the long-term skid resistance and is noted: "$\mu_{\text{WS-Final}}$" in this paper. Table 5 below shows the $\mu_{\text{WS-Final}}$ of the samples.

Table 5: Measured skid resistance on the surface samples after polishing using the WS machine

		$\mu_{\text{WS-Final}}$
Sample names	**A1**	0.20
	A2	0.36
	A3	0.26
	A5	0.17
	A6	0.28
	M1	0.42
	M2	0.35
	M3	0.11

Comparison between the estimated AHP_M and the measured long term skid resistance

Table 6 below summarises the $\mu_{WS\text{-}Final}$ and AHP_M measured and calculated for the samples and Figure 3 shows the correlation between them. Regarding Figure 3, one can notice that there is a very strong correlation between these two quantities, except for one point (corresponding to the A2). Surface A2 is 96% diorite and the discrepancy could perhaps be due to the remaining 4% the composition of which is not known. Otherwise, apart from this point, one can notice an increasing evolution of the long term skid resistance with respect to that of the Averaged Aggregate Hardness Parameter. Given these results, this last parameter seems to be able to quantify this skid resistance in the long term for all types of surfaces (asphalt or mosaic) whatever the mixture of aggregates.

Table 6: µWS-Final and AHP_M of the pavements

		AHP_M	**$\mu_{WS\text{-}Final}$**
Sample names	**A1**	4.72	0.20
	A2	6.38	0.36
	A3	6.63	0.26
	A5	3.92	0.17
	A6	6.95	0.28
	M1	15	0.42
	M2	10.1	0.35
	M3	3	0.11

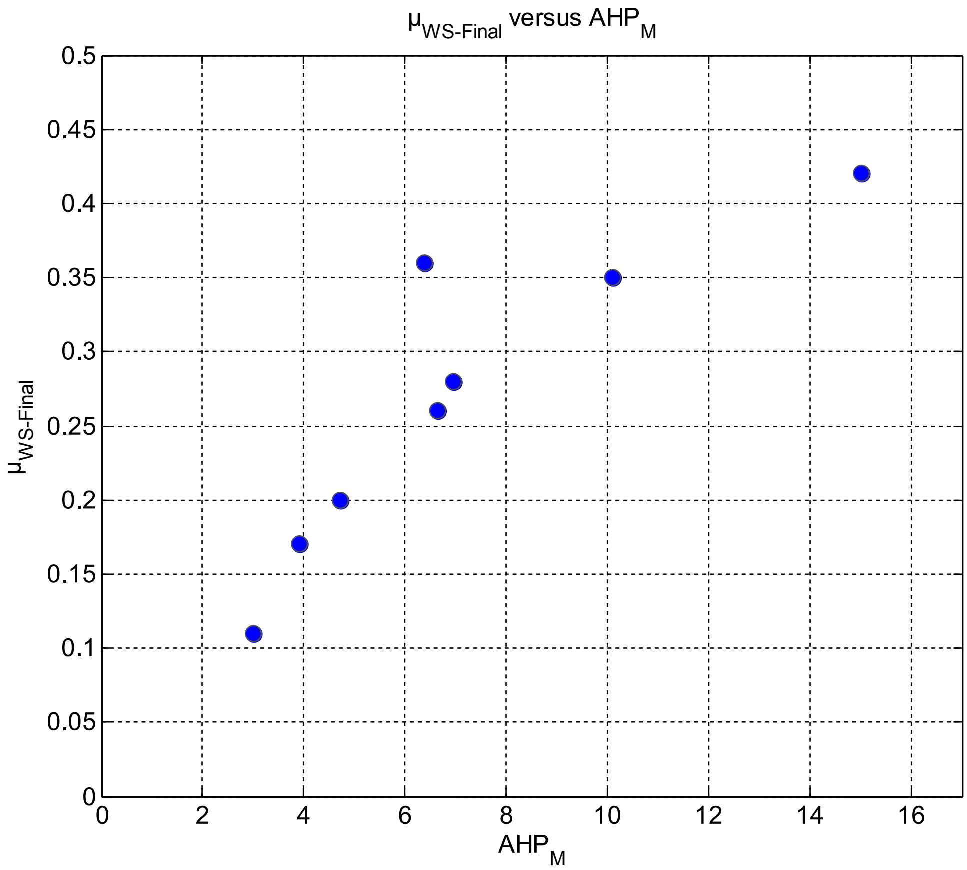


Figure 3: µWS-Final versus AHP_M

Towards analytical formulas for practitioners

To go further and thus enable practitioners to use the results of this study for applications, the authors have proposed to adjust an analytical function $\mu_{WS\text{-}Final}(AHP_M)$ to these data.

the evolution of the points, and the absolute limit values of $\mu_{WS\text{-}Final}$ dictated by physics that

$\mu_{WS\text{-}Final}(0) = 0$ and $\mu_{WS\text{-}Final}(+\infty) = 1$

the authors have proposed the function in Equation 5. However, even if the latter seems to correspond to physics, its adjustment remains weak for the last point with the highest AHP_M (Figure 4 - Left).

$$\mu_{\mathbf{WS-Final}}(AHP_M) = 1 - \exp(-\alpha \times AHP_M) \qquad 5$$

Where,

α is a constant and is equal to 0.045

For this reason, the authors have proposed a second empirical function (Equation 6), which, although it has no theoretical physics basis, fits well with the data set of results (Figure 4 - Right). The latter can be used by practitioners (as long as the AHP_M value remains within the interval [3 – 15] of this publication). To go beyond this, it will be necessary to complete the tests with surfaces with larger AHP_M 's.

$$\mu_{\mathbf{WS-Final}}(AHP_M) = \beta \log(AHP_M) - \lambda \qquad 6$$

Where, β*and* λ are constants respectively equal to 0.193 and 0.086

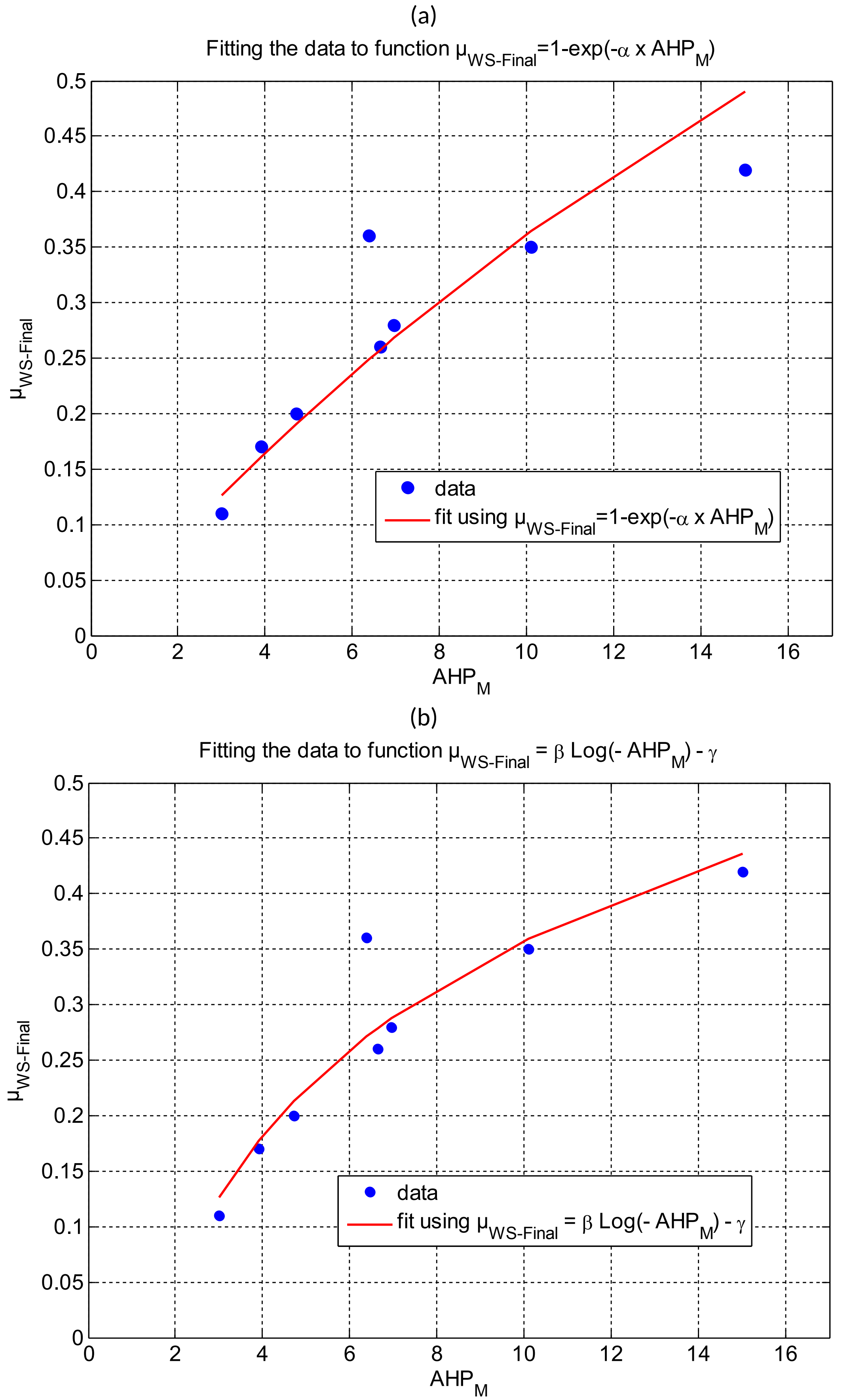


Figure 4: (a) – Fitting curve using an exponential function. (b) – Fitting curve using a logarithmic function

Conclusion

- The paper proposed a relationship between the types of coarse aggregates of asphalt mixes and their long-term skid resistance capacities. The focus is shifted from one type of aggregate in the asphalt mix to a mix of several types of aggregates.
- After rigorous testing comprised of lab polishing tests on different mosaics of aggregates and Asphalt Surfacings, friction measurements, and mineralogical analysis a newly proposed parameter called “Averaged Aggregate Hardness Parameter” was found to correlate well with the long-term skid resistance of the pavements.
- For practical use, analytical formulas are proposed to link this pavement hardness parameter and the long-term skid resistance of pavements. If the first analytical formula seems to correspond to physics, its adjustment remains weak for the point with the highest “Averaged Aggregate Hardness Parameter”. For this reason, the authors have proposed a second empirical function that can be used by practitioners
- To go beyond, it will be necessary to complete the tests on asphalt surfacings with different manufacturing conditions (the same aggregate size, compaction…).

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Dear Editor

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The authors declare that there no conflict of interest related to the paper titled "*Long-Term Skid Resistance of Asphalt Surfacings and Aggregates' Mineralogical Composition: Generalisation to Pavements made of Different Aggregate Types*" and submitted for consideration to be published in WEAR journal.

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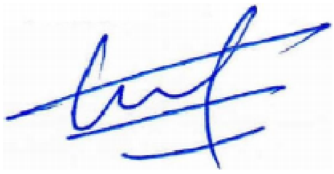

Dear Editor

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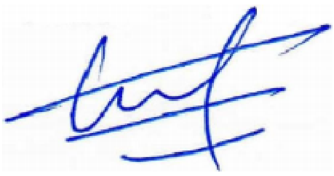
14/02/2020



Long-Term Skid Resistance of Asphalt Surfacings and Aggregates' Mineralogical Composition: Generalisation to Pavements made of Different Aggregate Types

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Abstract

The raw data here are used to calculate the AHPM ("Averaged Aggregate Hardness Parameter") parameters of pavement surfaces and to determine their capacity of skid resistance in the long term. They are composed by :

- the type of aggregates and their proportions by volume in each pavement,
- the calculated of the Aggregate Hardness Parameter (AHP) and
- the determined AHP of each of the pavements.

After the calculation of this parameter and with the help of analytical functions that we recall below, the skid Resistance capacity of that asphalt su, facing in the long term will be deduced. This long-term skid resistance value corresponds to that determined in the test with the Wehner Shulz machine.

Keywords

Long-Term Skid Resistance; Asphalt Surfacings; Aggregates' Mineralogical Composition; Petrographic nature; Aggregates types; Averaged Aggregate Hardness Parameter; Polishing, Traffic

Specifications Table

Subject	Civil and Structural Engineering

Specific subject area	Pavement engineering. The work aims to find the relationship between the types of coarse aggregates used in asphalt mixes and the long-term skid resistance capacity of the resulting pavements.
Type of data	Table
How data were acquired	Petrographic examination of aggregate samples was carried out under BS EN 932-3: 1997 [Kane et al., 2013].
Data format	Raw
Parameters for data collection	The general characteristics of the aggregate samples including maximum particle size, texture, and shape were examined and recorded. The main rock types were then identified and the relative proportions of the mineral constituents were estimated using a light (optical) microscope. Colour, grain size and degree of weathering were also recorded.
Description of data collection	To facilitate the quantitative examination, aggregate samples were sieved into separate size fractions and the mass of each size fraction determined. Each size fraction was then examined and the petrological composition was determined by hand separation and weighting [BS EN 932-3: 1997, Kane et al., 2013]. The method employed required two representative samples to be tested, with the result taken as the mean of the two measurements.
Data source location	Université Gustave Eiffel Campus de Nantes Allée des Ponts et Chaussées, 44340 Bouguenais, France
Data accessibility	With the article

Value of the Data

- This data is interesting because it allows you to follow the calculation procedure that leads to the parameter AHP.
- Anyone involved in asphalt mix design can use this data to predict the long-term skid resistance of his future surface.
- These data can be used and supplemented by other petrographic analyses of aggregates not included in this list.

Data Description

The file “Raw_Data.xls” is a excel file containing:

- The Sample characteristic including the type of aggregate and proportions by volume. The first letters “A” and “M” of the names of the samples gives their natures (“A” for Asphalt mixes and “M” for Mosaic) (Table 1),
- The Mineral composition of the aggregate contained in the samples (Table 2),
- The estimated AHP of each aggregate of the samples (Table 3),
- And the estimated AHPM of the surface samples (Table 4)

Experimental Design, Materials, and Methods

Petrographic examination of aggregate samples was carried out under BS EN 932-3: 1997 [Kane et al., 2013]. The general characteristics of the aggregate samples including maximum particle size, texture, and shape were examined and recorded. The main rock types were then identified and the relative proportions of the mineral constituents were estimated using a light (optical) microscope. Colour, grain size and degree of weathering were also recorded. To facilitate the quantitative examination, aggregate samples were sieved into separate size fractions and the mass of each size fraction determined. Each size fraction was then examined and the petrological composition was determined by hand separation and weighting [BS EN 932-3: 1997, Kane et al., 2013]. The method employed required two representative samples to be tested, with the result taken as the mean of the two measurements.

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[1] Kane M., Artamendi I., Scarpas T., Long-term skid resistance of asphalt surfacings: correlation between Wehner–Schulze friction values and the mineralogical composition of the aggregates, Wear 303 (1-2), 235-243, 2013

Method Article – Title Page

Title	Determination of the “Aggregate Hardness Parameter” related to the Long-Term Skid Resistance of Asphalt Surfacings
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Keywords	• Long-Term Skid Resistance; • Asphalt Surfacings; • Aggregates’ Mineralogical Composition; • Petrographic nature; • Aggregates types; • Averaged Aggregate Hardness Parameter; • Polishing, • Traffic
Direct Submission or Co-Submission *Co-submissions are papers that have been submitted alongside an original research paper accepted for publication by another Elsevier journal*	*Co-Submission* ○ WEA_2020_169

ABSTRACT

- This article describes the process for calculating the AHP (Averaged Aggregate Hardness Parameter) of a pavement surface (asphalt mixes) composed of several types of aggregates.
- After the calculation of this parameter and with the help of analytical functions that we recall below, the skid Resistance capacity of that asphalt surfacing in the long term will be deduced.
- This long-term skid resistance value corresponds to that determined in the test with the Wehner Shulz machine.

SPECIFICATIONS TABLE

Subject Area	Engineering
More specific subject area	Pavement engineering
Method name	Averaged Aggregate Hardness Parameter Determination
Name and reference of original method	
Resource availability	*If applicable, include links to resources necessary to reproduce the method (e.g. data, software, hardware, reagent)*

***Method details**

1st step: Determining the type of aggregate and proportions by volume

The first step is to determine the types of aggregates and their proportion in the mixture for the surface. As an example, see the Table 1:

Table 1: Surface characteristic including the type of aggregate and proportions by volume

		Aggregate types					
		Limestone	Basalt	Quatzite	Diorite	Greywacke	Granite
Surface names	A1	52	40	0	0	0	0
	A2	0	0	0	96	0	0
	A3	8	29	54	0	0	0
	A5	70	0	21	0	0	0
	A6	0	93	0	0	0	0
	M1	0	0	0	0	100	0
	M2	0	0	0	0	0	100
	M3	100	0	0	0	0	0

2nd step: Determination of the of the mineral composition of each of the aggregates

That step is dedicated to the determination of the mineral composition of each aggregate and hardness of each of these minerals via a petrographic examination. Each size fraction has to be then examined and the petrological composition has to be determined Table 2 displays the mineral composition of each aggregate of the Table 1.

Table 2: Mineral composition of the aggregate contained in the surfaces

Aggregate type	Mineral type	Mineral composition (%)	Mineral Hardness (H) (1 - 10)
Limestone	Calcite	100	3
Basalt	Pyroxene Feldspath Olivine	30 50 20	5,5 6 6,5
Diorote	Pyroxene Feldspath	25 75	5,5 6
Quartzite	Quartz	100	7
Greywacke	Quartz Feldspath Chlorite Biotite	52 16 22 10	7 6 2,5 3
Granite	Quartz Feldspath Amphibole Biotite	27 49 19 5	7 6 6 3

3rd step: Calculation of the Aggregate Hardness Parameter (AHP)

With the help of the three following equations, the mineralogical composition and the hardness of each of these minerals, the AHP parameter can be calculated for the type of aggregates:

$$\mathrm{dmp} = \sum_i \mathrm{dv}_i \times \mathrm{p}_i \qquad (1)$$

$$\mathrm{Cd} = \sum_i \left|\mathrm{dv}_i - \mathrm{dv}_p\right| \qquad (2)$$

$$\mathrm{AHP} = \mathrm{dmp} + \mathrm{Cd} \qquad (3)$$

where:

AHP means the Aggregate Hardness Parameter, dmp is the Average Hardness of the aggregates, Cd is the Contrast of Hardness of the aggregates, dv_i is the Moh's hardness of each mineral constituting the aggregates and p_i is the percentage by mass of each mineral constituting the aggregate. dv_p is the Moh's hardness of the most abundant mineral constituting the aggregate.

The following table (Table 3) gives an example of the AHP calculation based on the data in the above Table 2.

Table 3: Estimated AHP of each aggregate of the samples

Aggregate type	Mineral type	% x H	Average hardness (dmp)	Cd	AHP
Limestone	Calcite	3.0	3.0	0	3.0
Basalt	Pyroxene Feldspath Olivine	1.7 3.0 1.3	6.0	1	7.0
Diorote	Pyroxene Feldspath	1.4 4.5	5.9	0.5	6.4
Quatzite	Quartz	7.0	7.0	0	7.0
Greywacke	Quartz Feldspath Chlorite Biotite	3.7 1.0 0.5 0.3	5.5	9.5	15.0
Granite	Quartz Feldspath Amphibole Biotite	1.9 2.9 1.1 0.2	6.1	4.0	10.1

4th step: Determination of the AHP of the pavement
With the help of the following equation (4), the average AHP characterizing the pavement can be now calculated (Named AHP_M), from the AHP of each aggregate composing the pavement:

$$\mathrm{AHP_M} = \frac{1}{\sum_i^N \alpha i} \sum_i^N \alpha i \times \mathrm{AHP_i} \qquad 4$$

Table 4 shows the calculated AHP_M with the help of tables 1 and 3.

Table 4: Estimated AHPM of the surface samples

		AHPM
Sample names	A1	4.72
	A2	6.38
	A3	6.63
	A5	3.92
	A6	6.95
	M1	15
	M2	10.1
	M3	3

Declaration of interests:
☑ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

***References:**
Kane M., Artamendi I., Scarpas T., Long-term skid resistance of asphalt surfacings: correlation between Wehner–Schulze friction values and the mineralogical composition of the aggregates, Wear 303 (1-2), 235-243, 2013